

What is claimed is:

1. A solid oxide fuel cell system comprising
 - (a) at least one tubular solid oxide fuel cell comprising a ceramic
5 solid state electrolyte layer and inner and outer electrode layers
concentrically arranged around and sandwiching the electrolyte
layer, the inner electrode layer fluidly communicable with only
one of an oxidant reactant and a fuel reactant, and the outer
electrode layer fluidly communicable with only the other of the
10 oxidant and fuel reactants; and
 - (b) a combustion heater fluidly communicable with the oxidant and
fuel reactants such that combustion can occur, and mounted in
sufficient thermal proximity to the fuel cell that the fuel cell can
be heated by the combustion to an operating temperature.
- 15 2. A system as claimed in claim 1 further comprising a tubular thermal
casing, the inside of which defines a first reactant chamber that
contains the at least one fuel cell and the heater, and can contain the
reactant that is fluidly communicable with the outer electrode layer.
3. A system as claimed in claim 2 wherein the heater is fluidly
20 communicable with at least one of a fuel supply and unreacted fuel
exhausted from the fuel cell.
4. A system as claimed in claim 3 wherein the heater is tubular and has a
dense wall with an inside surface coated with catalytic material that is
effective to catalytically burn a mixture of the air and fuel flowing
25 through the heater.
5. A system as claimed in claim 3 wherein the heater is tubular and has a
sufficiently porous wall to enable the fuel and air mixture to pass
through the combustion heater into the reactant chamber, and the
pores are coated with catalytic material effective to combust a mixture
30 of the air and fuel flowing through the heater.

6. A system as claimed in claim 3 wherein the heater is tubular and is at least partly filled with a porous flame arrestor that has a maximum pore size that is smaller than the quenching diameter of the fuel.
- 5 7. A system as claimed in claims 4 or 5 wherein the heater further comprises an electric resistive element that generates sufficient heat to heat the catalytic material to an operating temperature.
8. A system as claimed in claims 4 or 5 wherein the heater comprises a flame burner fluidly communicable with the air and the fuel and operable to ignite the air and fuel to generate a flame and sufficient heat to heat the catalytic material to an operating temperature.
- 10 9. A system as claimed in claim 2 wherein the heater is tubular and the heater and casing are arranged to define an annular chamber therebetween that is fluidly communicable with an air and fuel mixture, and one or both of the heater and casing are coated with catalytic material effective to combust the air and fuel mixture.
- 15 10. A system as claimed in claim 9, wherein the inside of the tubular heater defines an oxidant chamber, and the system comprises the at least one fuel cell located within the oxidant chamber.
11. A system as claimed in claim 10 wherein the at least one fuel cell is embedded in a solid state porous foam matrix inside the oxidant chamber.
- 20 12. A solid oxide fuel cell system comprising
 - (a) at least one tubular solid oxide fuel cell comprising a ceramic solid state electrolyte layer and inner and outer electrode layers concentrically arranged around and sandwiching the electrolyte layer, the inner electrode layer fluidly communicable with only one of an oxidant reactant and a fuel reactant, and the outer electrode layer fluidly communicable with only the other of the oxidant and fuel reactants; and
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- 5 (b) a combustion heater comprising a first tube and a dense second tube within the first tube, the inside of the second tube defining a combustion chamber fluidly communicable with the oxidant and fuel reactants such that combustion can occur, and an annular space between the first and second tubes defining a reactant heating chamber fluidly communicable with one of the reactants and thermally coupled to the combustion chamber such that heat generated from the combustion is transferable to the reactant inside the reactant chamber.
- 10 13. A solid oxide fuel cell system as claimed in claim 12 wherein the heater is in sufficient thermal proximity to the fuel cell that the fuel cell can be heated to an operating temperature by the heat radiating and conducted from the heater.
- 15 14. A solid oxide fuel cell system as claimed in claim 13 wherein the reactant fluidly communicable with the outer electrode layer and the reactant heating chamber is oxidant, and the first tube is sufficiently porous to enable oxidant heated inside the heating chamber to pass through first tube and communicate with the outer electrode layer.
- 20 15. A solid oxide fuel cell system as claimed in claim 13 wherein the heater further comprises a fuel and oxidant pre-mixing chamber fluidly coupled to an inlet end of the combustion chamber, and fluidly communicable with the fuel and oxidant such that the fuel and oxidant are mixed therein.
- 25 16. A solid oxide fuel cell system as claimed in claim 15 wherein the combustion chamber is at least partly filled with a porous flame arrestor that has an average pore size that is smaller than the quenching diameter of the fuel.
- 30 17. A solid oxide fuel cell system as claimed in claim 13 wherein the heater further comprises a flame burner fluidly coupled to an inlet end of the combustion chamber, and fluidly communicable with the fuel and oxidant such that the fuel and oxidant are ignited to form a flame.

18. A solid oxide fuel cell system as claimed in claim 13 wherein the heater further comprises a porous third tube inside the second tube, an annular space in between the second and third tubes defining a combustion air chamber, and an inside of the third tube defining a combustion fuel chamber, the combustion air chamber fluidly communicable with the oxidant and the combustion fuel chamber fluidly communicable with the fuel at a higher pressure than the oxidant, thereby causing fuel to permeate radially through the third tube and into the combustion air chamber for combusting with the oxidant therein.
19. A solid oxide fuel cell system as claimed in claim 13 wherein the heater further comprises a porous third tube inside the second tube, an annular space in between the second and third tubes defining a combustion air chamber, and an inside of the third tube defining a combustion fuel chamber, the combustion air chamber fluidly communicable with the oxidant and the combustion fuel chamber fluidly communicable with the fuel at a lower pressure than the oxidant, thereby causing oxidant to permeate radially through the third tube and into combustion fuel chamber for combusting with the fuel therein.
20. A solid oxide fuel cell system as claimed in claim 13 wherein the heater further comprises a porous third tube inside the second tube, an annular space in between the second and third tubes defining a first combustion chamber, and an inside of the third tube defining a second combustion chamber, the first combustion chamber having an exhaust outlet and the combustion fuel chamber fluidly communicable with the fuel and oxidant, the fuel and oxidant forming a mixture therein that permeates radially through the third tube and into the first combustion chamber for combusting.
21. A solid oxide fuel cell system as claimed in claim 20 further comprising an flame igniter in the first combustion chamber and effective to ignite the fuel and oxidant mixture therein for combustion by flame burning.

22. A solid oxide fuel cell system as claimed in claim 20 or 21 wherein the pores of the third tube are coated with a catalytic material sufficient to catalytically combust the oxidant and fuel mixture passing therethrough.
- 5 23. A solid oxide fuel cell system of claim 1 wherein the combustion heater comprises a porous outer tube and a porous inner tube within the outer tube, an inside of the inner tube defining an inner combustion chamber fluidly communicable with the oxidant and fuel reactants which form a mixture therein, and an annular space between the first and second
10 tubes defining an outer combustion chamber in which fuel and oxidant mixture radially permeating through the inner tube is combusted.
24. A solid oxide fuel cell system of claim 23 further comprising a flame igniter in the outer combustion chamber and effective to ignite the fuel and oxidant mixture therein for combustion by flame burning.
- 15 25. A solid oxide fuel cell system as claimed in claim 23 or 24 wherein the pores of the inner tube are coated with a catalytic material sufficient to catalytically combust the oxidant and fuel mixture passing therethrough.
26. A solid oxide fuel cell system as claimed in claim 5 further comprising a
20 tubular flame arrestor surrounding the heater, the flame arrestor having pores or perforations with a maximum size that is smaller than the quenching diameter of the fuel.
27. A solid oxide fuel cell system as claimed in claim 10 further comprising
25 a porous flame arrestor located in the annular chamber and having a maximum pore size smaller than the quenching diameter of the fuel-air mixture flowing through the annular chamber.
28. A solid oxide fuel cell system as claimed in claim 27 wherein the flame
30 arrestor is a porous or perforated cylindrical layer located in the annular chamber such that a pair of annular compartments are defined on either side of the cylindrical layer, wherein one compartment is large enough to receive an air/fuel mixture and distribute the mixture

uniformly through the cylindrical layer, and the other compartment has a thickness large enough for flames to form therein.

29. A solid oxide fuel cell system as claimed in claim 10 further comprising a cylindrical porous catalytic layer located inside the annular chamber such that a pair of annular compartments are defined on either side of the layer and composed of a porous material with pores coated with catalytic material that promotes combustion of a fuel/air mixture in the annular chamber.
30. A fuel cell system comprising:
- at least one tubular solid oxide fuel cell comprising a ceramic solid state electrolyte layer and inner and outer electrode layers concentrically arranged around and sandwiching the electrolyte layer, the inner electrode layer fluidly communicable with only one of an oxidant reactant and a reformat fuel reactant, and the outer electrode layer fluidly communicable with only the other of the oxidant and fuel reactants; and
- a reformer fluidly coupled to a fuel inlet end of the at least one fuel cell and comprising reformer catalytic material that reforms hydrocarbon fuel into reformat fuel.
31. A system as claimed in claim 30 wherein the reformer is a porous reformer catalyst material at least partially filling the inside of each fuel cell at the fuel inlet end.
32. A system as claimed in claim 30 wherein the reformer comprises a tube at least partially filled a porous reformer catalyst material, the reformer tube having a discharge end fluidly coupled to the fuel inlet end of each fuel cell.
33. A system as claimed in claim 30 further comprising a fuel inlet manifold assembly fluidly coupled to the fuel inlet end of each fuel cell, communicable with a hydrocarbon fuel source, and at least partially filled with a porous reformer catalyst material.